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Biodiesel Production from Castor Oil in the Liquid Phase using Acidic Alumina as A Catalyst

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Abstract

Biodiesel is technically defined as alkyl esters of long chain fatty acids derived from vegetable oils or animal fats. It is eco friendly fuel as compared to petroleum-based hydrocarbons. This renewable and biodegradable advantage makes biodiesel is as a good sustainable energy carrier. It is usually produced by a trans-esterification reaction of vegetable or waste oil with a low molecular weight alcohol, such as ethanol and methanol. In this present work, ethanol is used for the production of biodiesel by using castor oil as a source material and acidic alumina as a catalyst. Experimental conditions like effect of time, temperature, molar ratio, catalyst dosage are optimized to obtain maximum conversion. The product is characterized by FT-IR and NMR.

Key words: *Alumina; Biodiesel; Catalyst; Energy.*

1. INTRODUCTION

Biodiesel is technically defined as alkyl (usually methyl and ethyl) esters of long chain fatty acids derived from vegetable oils or animal fats. When used as fuel in diesel engines and heating systems, biodiesel has many merits, such as high energy density, more favorable combustion emission profile, improved lubricating properties and others. It is also an environmental friendly fuel compared to petroleum-based diesel, as biodiesel is renewable, biodegradable, non-toxic, free of sulfur and aromatics (Yamane *et al.* 2001).

Since the demand and cost of petroleum based fuel is growing rapidly, and if the present pattern of consumption continues, these resources will be depleted in few years. Hence, efforts are being made to explore for alternative source of energy. Currently, biodiesel is becoming one of the best alternative fuel in most of the countries. Directly or blended edible or non-edible oil can be used in diesel engine and at the same time it can create problem in engine because of its high viscosity (Pramanik, 2003; Knothe *et al.* 2005). Biodiesel is produced using edible oil, non-edible oil and animal fats by acid or by base catalyzed transesterification with ethanol or methanol (Murugesan *et al.* 2009; Ma and Hanna, 1999).

The present work explains the transesterification of castor oil with ethanol in the presence of Alumina as catalyst. The castor nut which contains approximately 90% of ricinoleic acid is quite available in our (India) country. So it is used as a source material for the current research.

2. MATERIALS & METHODS

Catalytic Reaction

Acidic alumina is used as the catalyst for the synthesis of biodiesel; castor oil and ethanol are taken as a reactant for the synthesis of biodiesel. The acidic alumina and ethanol is purchased from lobachem pvt. Ltd., Molecular formula is Al_2O_3, and molecular weight is 101.96g/mol and particle size of acidic alumina is 70-230 mesh. The pH of acidic alumina is 3.5 to 5. The reaction mixture is taken in a two necked 100 ml round-bottom flask and it is placed in an electrical heating mantle with an energy regulator. To the central neck of the flask fitted with a condenser and to the side neck is fixed with mercury well for the thermometer. The flask is heated gently and with controlled temperature. The product formed is now in the form of biodiesel and residual glycerol. Then the product mixture was filtered and separated from the catalyst.

Material Characterization

The structure of the catalyst is determined by Fourier transform infrared (FT-IR) analyzer using

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JASCO-410 FT-IR Spectrometer. This analysis was performed by mixing dried carbon sample with potassium bromide (KBr). The spectra were acquired in the range of 400-4000 cm^{-1}. The FT-IR spectra of acidic alumina are shown in Fig. 1. A peak at 1605 cm^{-1} is attributed to the Al-O-Al asymmetric stretching. The corresponding symmetric stretching vibration is observed at 606 cm^{-1}. It is confirmed that the acidic alumina has no tetrahedral frame work. The strong peak at 3640 cm^{-1} is attributed to the Al-OH stretching mode. This OH is an active site for transesterification reaction.

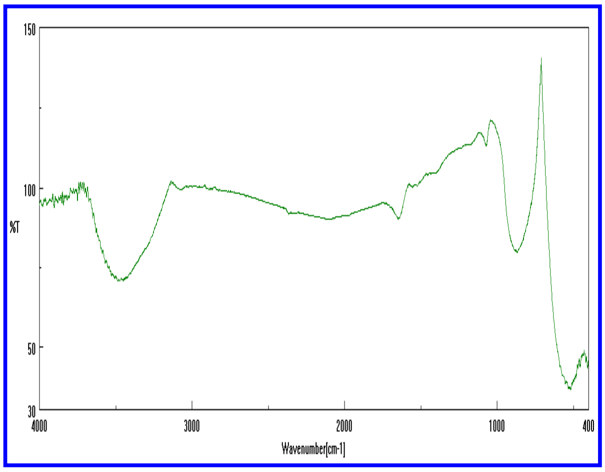

Fig. 1: FT-IR spectrum of acidic alumina

3. RESULT & DISCUSSION

The transesterification of castor oil is carried out over low-cost and non- hazardous acidic alumina catalyst in liquid phase. The conversion of castor oil increases rapidly above 120-150 °C. The time required for the transesterification of castor oil, effect of temperature, contact time, effect of alcohol to oil mole ratio, effect of catalyst dosage are optimized to achieve better conversion.

Effect of Time

The castor oil transesterification reaction can be studied at different time intervals. It may be noticed that after 30-45 minutes, approximately 28% of product conversion observed within the first one hour. The percentage of conversion increased with increase of time, and attained a maximum conversion at 3 hours. Further increase of time there is no significant increment in transesterification reaction. The conversion is 33.8% at 3 hours indicated the formation of transesterification reaction occurs rapidly in the presence of acidic alumina (Fig. 2).

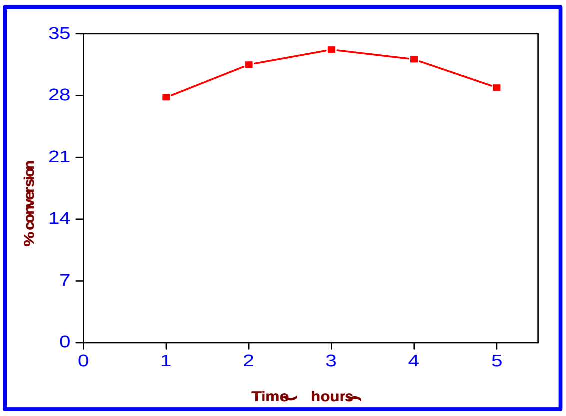

Fig. 2: Effect of time on castor oil transesterification reaction over acidic alumina, Castor oil amount-5ml, Ethanol-0.9ml (1:3 mole ratio), Temperature-150 °C, catalyst weight-0.1gm

Effect of Temperature

The temperature effect of castor oil with ethanol transesterification reaction over acidic alumina is shown in Fig. 3. The temperature effect has been studied from 60-200 °C. The conversion of the reaction is 20% from 60-150 °C. Further increased of temperature conversion of castor oil is significantly increases upto 150 °C. This study proved that the optimum temperature for the castor oil conversion is 150 °C.

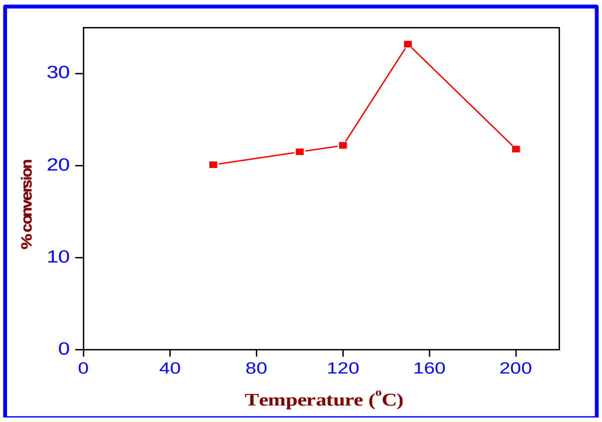

Fig. 3: Effect of temperature on castor oil with ethanol transesterification reaction over acidic alumina. Catalyst weight-0.1gm, castor oil-5ml, ethanol-0.9ml (1:3 mole ratio), Time -3hours.

Effect of molar ratio

The effect of mole ratio of castor oil and ethanol over acidic alumina in liquid phase is shown in Fig. 4. The mole ratio of castor oil and ethanol has been studied

from 1:3 to 1:15. The conversion is maximum at 1:15 mole ratio. It indicates that when mole ratio increases, the percentage of product also increases.

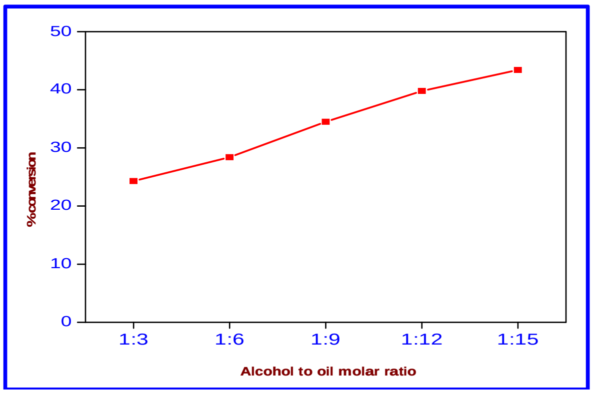

Fig. 4: Effect of castor oil with ethanol dosage on transesterification reactiom over acidic alumina Time-3 hours, Catalyst weight-0.1 gm, Temperature – 150 °C

Effect of catalyst dosage

Catalyst dosage effect on castor oil with ethanol transesterification reaction over acidic alumina in the liquid phase at 150 °C has been studied to find out the linear relationship between the active sites present on surface of catalyst and castor oil transesterification reaction is shown in the fig. 5. In this study, the percentage of conversion of biodiesel increased with increasing of catalyst amount. This clearly proved that the castor oil transesterification has a linear relationship with the catalyst amount. When the catalyst amount increased the active sites and the surface of the catalyst also increased. Hence the conversion of castor oil increases with increase of catalyst amount.

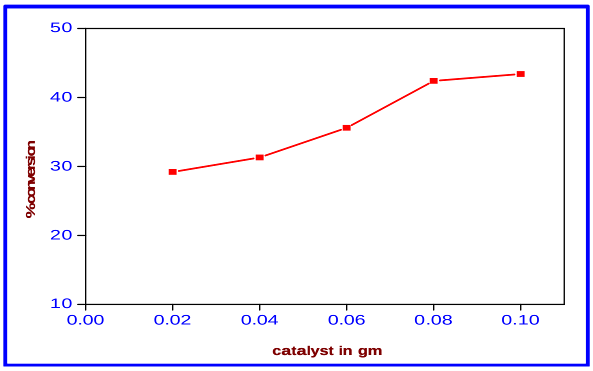

Fig. 5: Effect of catalyst amount on castor oil transesterification reaction over acidic alumina. Castor oil - 5ml, Time-3hours, Temperature-150 °C.

CHARACTERIZATION OF CASTOR OIL AND BIODIESEL

FT-IR Spectrum of castor oil:

FT-IR spectrum of castor oil is shown in Fig. 6. The castor oil contains a hydroxyl component at 3409 cm^{-1}. The peaks at 2928-2855cm^{-1}, 1744 cm^{-1} and 1462cm^{-1} corresponding to CH, C=O and C=C stretching. This FT-IR proved the structure of castor oil.

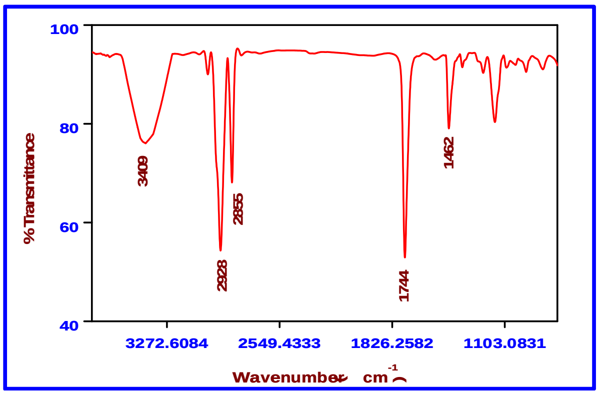

Fig. 6: FT-IR spectrum of Castor oil

FT-IR spectrum of biodiesel

The synthesized biodiesel over acidic alumina in the liquid phase is characterized by FT-IR spectrum to confirm the biodiesel structure and it is shown in Fig. 7. The ester group is observed from 1740 cm^{-1} and the peak exist at 1176 cm^{-1} representing the CH_2 stretching band. The C=C group is observed at 2357 cm^{-1} and the peak at 2930 cm^{-1} representing the CH, C=O and CH stretching band (Mushtaq Ahmad *et al.* 2011; Kumar Ved and Kand Padam, 2013). The intense band exists near 1740 cm^{-1} represents the ester group present in the biodiesel.

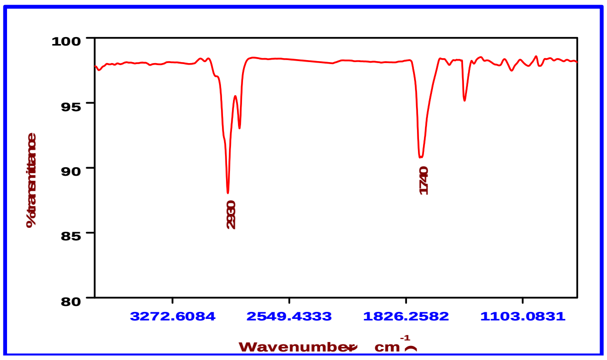

Fig.7: FT-IR spectrum of biodiesel ¹H NMR spectrum of biodiesel

The synthesized biodiesel is characterized by ^{1}H NMR spectroscopy is shown in fig. 8. In ^{1}H NMR spectrum, the strong peak at 3 - 4 ppm indicates the ethyl ester formation. The peak obtained at 2.1 ppm result from the protons on the CH_2 groups adjacent to the ethyl ester. α-CH_2 protons was appeared at 2.23 ppm. These observed peaks from ^{1}H NMR spectrum proved the sformation of biodiesel in liquid phase over acidic alumina as the catalyst.

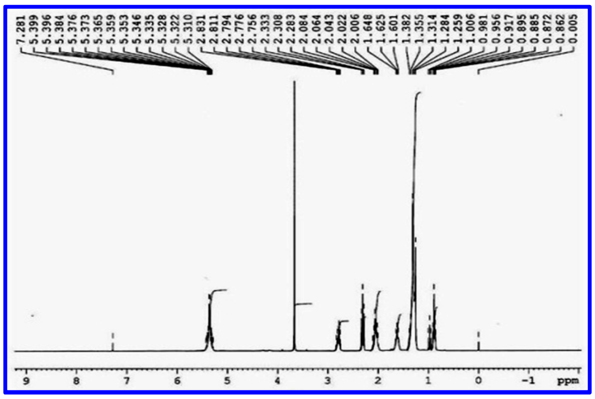

Fig. 8: Proton NMR Spectrum for castor oil biodiesel

4. CONCLUSION

In the present investigations, the castor oil transesterification has been studied through green chemistry method. The castor oil with ethanol transesterification over acidic alumina has been studied in the liquid phase. The experimental conditions like contact time, effect of temperature, amount of castor oil with ethanol ratio and catalyst amount has been optimized for maximum conversion. The contact time effect has been studied from 1 to 5 hours and found that maximum conversion is attained at 3 hour and further increase of time no significant increment of conversion. The temperature effect has been studied from 60 ^{o}C to 150 ^{o}C and found that the conversion is maximum for 150 ^{o}C for biodiesel**.** The synthesized biodiesel was characterized by FT-IR spectrum, the ester group vibration (1745 cm^{-1}), CH_2group vibration (1176 cm^{-1}), the C=C group vibration (2357 cm^{-1}) and the CH stretching (2929 cm^{-1}) were observed in FT-IR spectrum. It is proved the formation of biodiesel.

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